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DESIGN AND CONSTRUCTION OF ROBUSTA COFFEE BEAN ROASTING EQUIPMENT (*Coffea canephora*)

RANCANG BANGUN ALAT PENYANGRAI BIJI KOPI ROBUSTA (*Coffea canephora*)

Yusran Akbar[1], Umar Husein Abdullah[1*], Rian Aulia[2], Sri Agustina[2]

[1]Plantation Management, Politeknik Indonesia Venezuela.
[2]Agroindustry, Politeknik Indonesia Venezuela

* Correspondent Author : umarah_1977@yahoo.co.id

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Abstract

This study aims to design a roaster to produce three roasting categories: light roast, medium roast, and dark roast and obtain quality coffee beans. The research was conducted in the laboratory of the Agricultural Mechanization Workshop of the Politeknik Indonesia Venezuela. This research uses the Trial and Error method. This research uses the Trial and Error method. During the process of roasting coffee beans, observations were made of temperature, length of time and knowing the maximum capacity of the tube and the maximum temperature level of roasting. The design of the coffee bean roaster is also classified as different from other tools or machines because it uses a heating element (heater) that can be adjusted according to the roasting desire. The response method in this study includes the temperature and length of time used during the roasting process where a system to control the situation so that the results obtained correspond to the desired value as effectively as possible. Based on the results of functional and structural tests, the roaster that has been designed can work properly. The capacity of the roasting tube that has been designed produces a volume of 9.42 liters equivalent to a coffee weight of 2 kg. The working capacity of the tool produces 2.4 kg/hour for Light Roast criteria, for Medium Roast criteria produces 1.7 kg/hour, and for Dark Roast criteria produces 0.8 kg/hour. The average temperature distribution for Light Roast material is 97 ° C, Medium Roast is 110.83° C, and Dark Roast is 131.25° C.

Keywords **:** *Design, Arabica Coffee, Roasters, Temperature*

Abstrak

Penelitian ini bertujuan untuk merancang alat penyangrai agar menghasilkan tiga kategori *roasting* yaitu : *light roast, medium roast,* dan *dark roast* serta mendapatkan biji kopi yang berkualitas. Penelitian telah dilaksanakan di laboratorium bengkel Mekanisasi Pertanian Politeknik Indonesia Venezuela. Penelitian ini menggunakan metode *Trial and Error.* Penelitian ini menggunakan metode *Trial and Error.* Selama proses penyangraian biji kopi dilakukan pengamatan terhadap suhu, lama waktu serta mengetahui kapasitas maksimum tabung dan tingkat suhu maksimum penyangraian. Perancangan alat penyangrai biji kopi juga tergolong berbeda dengan alat atau mesin lainnya karena menggunakan elemen pemanas *(heater)* yang dapat disesuaikan suhunya sesuai dengan keinginan roasting. Metode respon pada penelitian ini yaitu meliputi suhu dan lama waktu yang digunakan selama proses penyangraian dimana suatu sistem untuk mengendalikan keadaan sehingga diperoleh hasil bersesuaian dengan nilai yang

diinginkan seefektif mungkin. Berdasarkan hasil uji fungsional dan struktural, maka alat penyangrai yang sudah dirancang dapat bekerja dengan baik. Kapasitas tabung penyangrai yang sudah dirancang menghasilkan volume sebesar 9,42 liter setara dengan berat kopi sebesar 2 kg. Kapasitas kerja alat menghasilkan 2,4 kg/jam untuk kriteria *Light Roast*, untuk kriteria *Medium Roast* menghasilkan 1,7 kg/jam, dan untuk kriteria *Dark Roast* menghasilkan 0,8 kg/jam. Rata-rata pendistribusian suhu untuk bahan *Light Roast* sebesar 97°C, *Medium Roast* sebesar 110,83°C, dan *Dark Roast* sebesar 131,25°C.

Kata Kunci : Rancang Bangun, Kopi Arabika, Alat penyangrai, Suhu, .

INTRODUCTION

Coffee is one of the plantation commodities that has a high economic value among other plantation crops and plays an important role as a source of foreign exchange. Coffee not only plays an important role as a source of foreign exchange but also a source of income for no less than one and a half million coffee farmers in Indonesia. The success of coffee agribusiness requires the support of all parties involved in the production process of coffee processing and marketing of coffee commodities. Efforts to improve coffee productivity and quality continue so that the competitiveness of coffee in Indonesia can compete in the world market (Raharjo, 2017).

Roasting is the process of frying coffee without using oil. Coffee roasting is basically a process of changing the chemical and physical properties of coffee, in this case the aroma, sourness and various flavors present in coffee. Grinding coffee is the process of grinding roasted coffee into coffee powder. In general, the process of roasting and grinding coffee is done in the traditional way and separately (Amiq et al., 2015). The roasting process is carried out using high temperatures. Coffee beans are roasted at 180-240°C, usually taking 15 to 20 minutes. During roasting, the coffee beans are stirred so that the water vapor is quickly carried out and the heat is uniformly distributed throughout (Sari, 2018).

Design is the initial activity of a series in the product manufacturing process. In the design stage, important decisions are made that will affect other activities that follow. The design process is carried out before the manufacture of a product and produces a description of the product to be made. In the design process, it will produce a simple drawing which is then drawn again according to the rules so that it can be understood by everyone (Wahyujati, 2022).

In designing a machine element there are several aspects that must be considered. One of these aspects is the selection of the type of engineering material to be used. The choice of material for an element or component greatly affects the strength of the element. Determination of the right material is basically a link between various properties, the environment, and the way of use until the properties of the material can meet predetermined requirements (Setiono et al., 2016). The purpose of this research is to design a roaster to produce three roasting categories, namely: light roast, medium roast, and dark roast and get quality coffee beans.

RESEARCH METHODS

Place and Time of Research

The research was conducted in the laboratory of the Agricultural Mechanization Workshop of the Politeknik Indonesia Venezuela.

Tools and Materials

The tools and materials used in this research can be seen in Table 1 as follows:

Table 1. Tools and Materials

Tools	Material	
Welding Tools	Heater (Heating Element)	Design Material
Grinding	Galvanis Plate	
Drill	Brace Iron	
Pliers	Shaft	
Screwdriver	Bearing	
Obeng	Thermostat	
Thermometer		
Hammer	Robusta Coffee Bean	Tes Material
Scales		
Stopwacth		

Research Method

This research uses the Trial and Error method. The process of designing a coffee bean roaster to find the advantages, disadvantages, and benefits that will be obtained from the process of designing a coffee bean roaster. During the process of roasting coffee beans, observations are made of temperature, length of time and knowing the maximum capacity of the tube and the maximum temperature level of roasting. The design of the coffee bean roaster is also classified as different from other tools or machines because it uses a heating element (heater) that can be adjusted according to the roasting desire.

The response method in this study includes the temperature and length of time used during the roasting process where a system to control the situation so that the results obtained correspond to the desired value as effectively as possible. There are two types of data used in this study, namely: quantitative and qualitative data, the data sources used are: primary data and secondary data. Primary data is data that is first recorded and collected by the author. Primary data in this study was obtained by making observations of the results of the design of the coffee bean roaster. Secondary data is data obtained in the form of documents from research activities, literature in articles that are relevant to the object of research. For example reference books,

general and international journals, additional literature whose validity can be accounted for by researchers.

Analisys Tool

The analysis tool in designing a coffee bean roaster uses the equation formula, namely: measurement of the volume of the roaster tube and the equation formula for the volume of coffee beans.

Volume of Roasting Tube

$$Vt = \pi * r^2 * t$$

Where :

Vt = Volume of Roasting Tube

$\pi = \frac{22}{7}$

r = Roaster Tube Radius
h = Roaster Tube Height

Coffee Bean Volume

$$Vb = \frac{4}{3} \pi * r^3$$

Where :

Vb = Coffee Bean Volume
$\pi = \frac{22}{7}$
r = Coffee Bean Radius

Tool Test Capacity

$$TTC = \frac{BK}{T}$$

Where :

TTC = Tool Test Capacity
T = Time (Hours)
CB = Coffee Beans

Design and Construction Drawings of Coffee Bean Roaster

The design of the coffee bean roaster is expected to be utilized and fulfill the shortcomings of the existing tools / machines. So that the design of a coffee bean roaster is determined on various considerations as follows:

1. The design of a coffee bean roaster is expected to be able to roast coffee beans on a on a household scale and get a distinctive aroma flavor during the roasting process. the process of roasting coffee beans.
2. The coffee bean roaster does not use a machine but is done manually using human labor. manually using human labor.
3. Ecogonomic tool specifications with dimensions that are comfortable for the operator and easily adapted to the workspace. and easily adapted to the workspace of the tool with dimensions of 30 cm long * 25 cm wide * 25 cm high.
4. Easy to operate and maintain the tool.

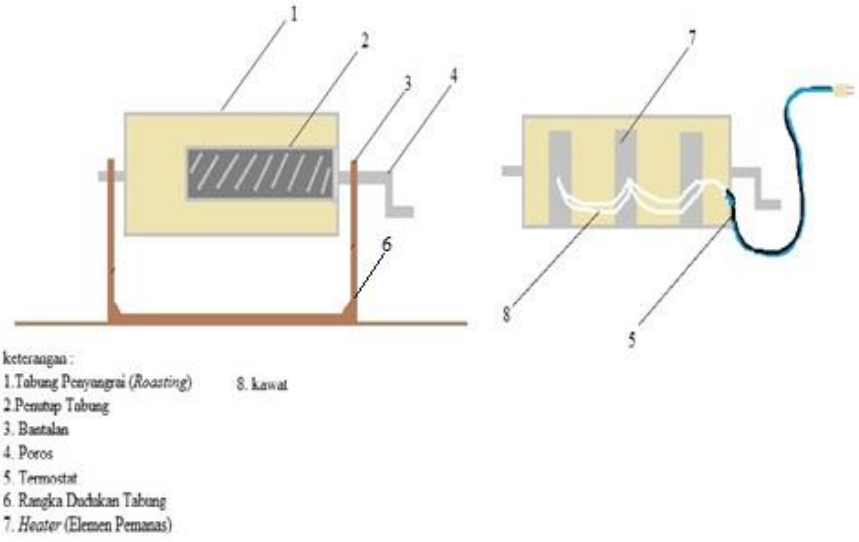

Figure 1. Design and Drawings of the Coffee Bean Roaster Design

Research Procedure

1. Studying the size of coffee beans: the physical characteristics of agricultural materials are very important factors in dealing with problems related to designing a special machine for an agricultural product or analyzing the behavior of the product and how to handle it. The analysis of physical characteristics carried out by this research material is the measurement of coffee beans. Measurements are made using a push term. The measurement results obtained are: Coffee bean height (T) (major axis) is 1.08 cm and coffee bean diameter (D) (minor axis) is 0.47 cm.

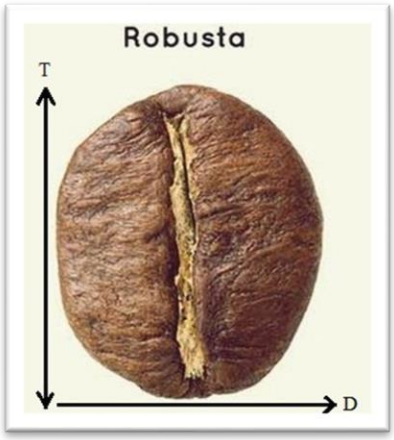

Figure 2. Robusta Coffee Beans

2. Roasting coffee beans aims to reduce the moisture content and acidity level contained in coffee beans so that the distinctive flavor and aroma of coffee beans during the roasting process can be felt.
3. Making the design concept at this stage, the concept of making the shapes of the roasting tube components is carried out.
4. The next step is to install the main components and arrange other supporting components.
5. Construction at this stage is carried out calculating and making frames, using shafts and using transmission systems and other components.

Performance Test Preparation

The initial preparation for the performance test is to prepare the raw materials and tools used during the implementation of the coffee bean roasting process, including:

1. Robusta coffee beans as much as 2 kg
2. Thermometer as a roasting temperature gauge

Coffee beans are put into the roaster tube. Connect the heating element cable (heater) to the electric current. Coffee beans are roasted for ± 30 minutes and check the temperature with an interval of 5 minutes using a thermometer. During the roasting process, check the coffee beans to see the condition of the maturity of the coffee beans. Furthermore, the roasted coffee beans are removed through the roaster tube door. The coffee beans are then cooled for further processing.

RESULTS AND DISCUSSION

Structural and Functional Testing Results

Structural and functional tests are tests of each component contained in the design of a coffee bean roaster. This test is carried out to determine the performance of each component so

that it can function properly when the tool is operated. Structural functional tests on the design of the coffee bean roaster tool are carried out on several components of the tool, among others:

1. Tool Frame

The frame is an important part as a tool support so that it can stand firmly when operated. The choice of materials and the right connection process will affect the strength of the frame as a tool support so that the frame can withstand the maximum load expected (Anshori, 2021; Palinggi, 2023). The specifications of this frame have dimensions of 30 cm frame length, 25 cm frame width and 25 cm frame height using a behel iron with a diameter of 10 mm. The dimensions of the tool frame can be seen in Figure 3 as follows:

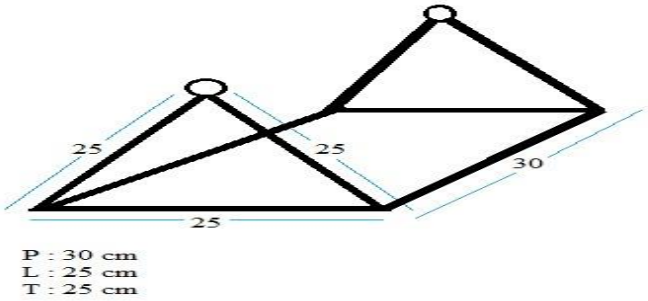

Figure 3. Tool Frame

2. Power Distribution

This coffee bean roaster has a transmission system consisting of a heater (heating element). Transmission design is adapted to the use of tubes. In the transmission system, the design of the tube drive on the coffee bean roaster is done manually, namely by connecting the drive lever at the end of the roaster tube shaft with the size of the lever used 1 inch and 1 m long, which functions as a driver.

3. Roasting Tube

The roaster tube is a component or part that functions as a place where coffee beans are roasted, the roaster tube is made of galvanized iron with a thickness of 2 mm which is formed in the form of a cylinder with dimensional specifications of 20 cm in diameter with a tube length of 30 cm in a horizontal position. The heating source in this roasting tube comes from a heater (heating element) which converts electric current into heat energy. The tube dimensions can be seen in Figure 4 as follows:

Figure 4. Roasting Tube

Roasting tube volume calculation equation:

$Vt = \pi * r^2 * t$

$Vt = 3{,}14 * (10\ cm)^2 * 30\ cm$

$Vt = 9.420\ cm^3 = 9{,}420\ dm^3 = 9{,}42$ liter

Equivalent to = 2 kg Coffee Beans

4. Heating Element (Heater)

The heating element used in the design of this coffee bean roaster consists of 3 roller-shaped heating elements with dimensions of 4 cm high and 14 cm in diameter. This element functions as a heat source which aims to heat the roaster tube as the most important main component in the design of the coffee bean roaster, which converts electrical energy into heat energy, the heating element is made of a clot (roll) of high electrical resistance wire / tape (niklin), which is then coated with a heat-resistant insulator (mica), and on the outside is coated again by a metal plate made of brass, aluminum or stainless steel which is then formed into a stripe-shaped heater plate (Hakim, 2022; Khudori, 2022). This stripe shape is rounded with a roller machine so that it becomes a belt shape whose diameter is adjusted as needed. The heating element (heater) can be seen in Figure 5 as follows:

Figure 5. Heating Element (heater)

Tool Performance Test

The performance test of the roasting tube on the coffee bean roaster is an effort to find out how the work and efficiency of the tool that has been made (Rusnadi, 2018). This test also aims as a step to monitor the shortcomings of the roaster that have not been followed up. Testing is also carried out on each component in the tool which aims to determine whether all components can function properly as expected. So that improvements and innovations can be made to the coffee bean roasting tube.

Kapasitas Tabung Penyangrai

Based on the results of measuring the volume of the roaster tube, the tube has a volume of 9,420 cm3 with a maximum capacity of 9.42 liters of water volume with a maximum capacity of 2 kg of coffee beans. The maximum capacity of coffee beans is obtained from the calculation of the equation formula as follows:

Coffee Bean Dimensions $= \frac{1}{4} x\ \pi * r^3$

$= \frac{4}{3} * 3{,}14 * (1{,}76)^3$

$= \frac{4}{3} * 3{,}14 * 5{,}45$

$= \frac{4}{3} * 17{,}11$

$= \frac{68{,}47}{3}$

$= 22{,}82\ cm^3$

Tool Working Capacity

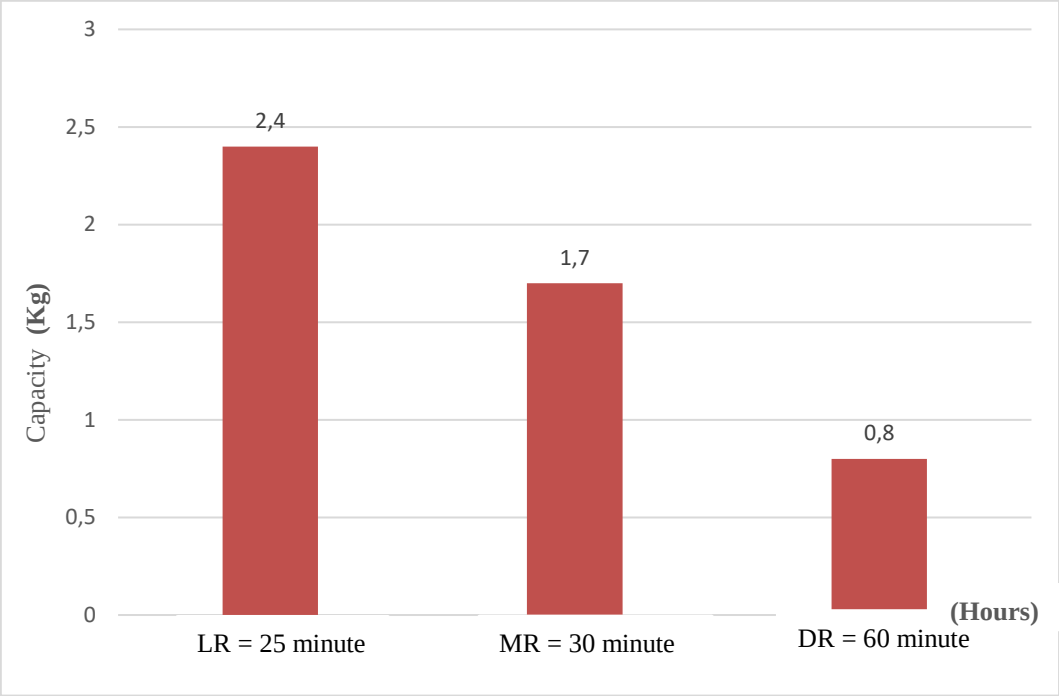

Figure 6. Tool Working Capacity

Based on Figure 6 above, it can be seen that the results of the working capacity of the tool are in the roasting process with Light Roast criteria resulting in a tool working capacity of 2.4 kg/hour, Medium Roast criteria of 1.7 kg/hour and with Dark Roast criteria of 0.8 kg/hour. This is a decrease in the working capacity of the tool from the roasting process with Light Roast to Dark Roast criteria, due to the length of time generated for each of these criteria (Batubara et al., 2018; Priyadi et al., 2023).

In Figure 7, it can be explained that the average temperature result with the Light Roast criteria is 97 ° C with 25 minutes, Medium Roast is 110.83 ° C with 30 minutes, and the Dark Roast temperature distribution is 131.25 ° C with 60 minutes. This happens because it is caused by the length of temperature distribution from 0 minutes to 60 minutes. The effect of the length of time used ranges from 25 (Minutes), 30 (Minutes), 60 (Minutes), with a minimum temperature of 170 ° C to a maximum temperature of 205 ° C (Wandani, 2018; Fadri et al., 2022).

Temperature Distribution

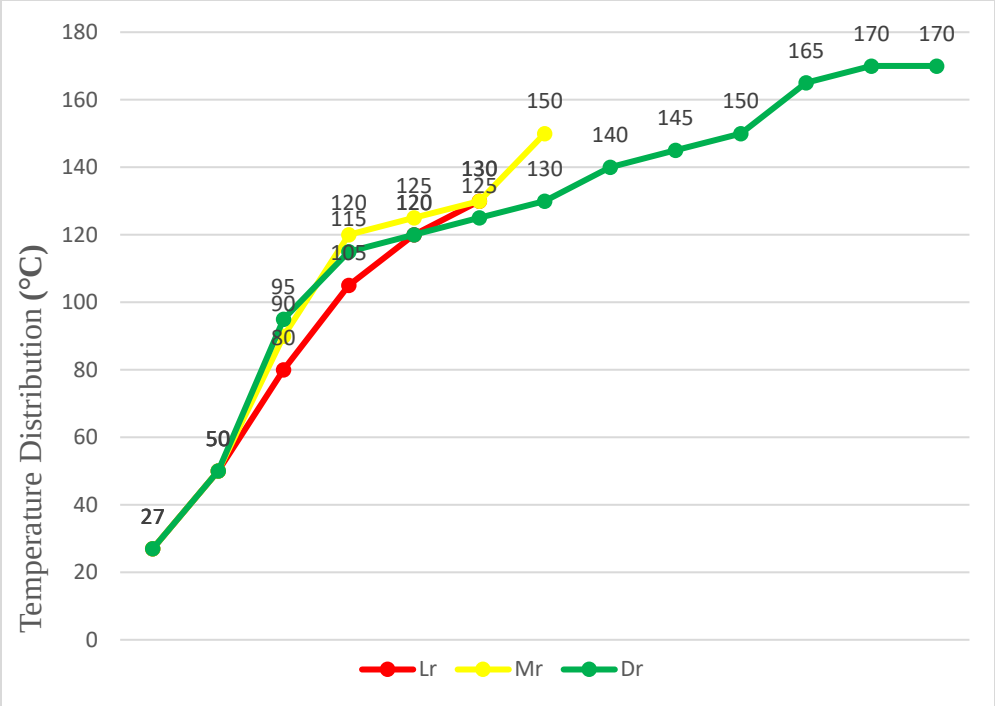

Figure 7. Temperature Distribution Once Every Five Minutes

CONCLUSION

Based on the results of functional and structural tests, the roaster that has been designed can work properly. The capacity of the roasting tube that has been designed produces a volume of 9.42 liters equivalent to a coffee weight of 2 kg. The working capacity of the tool produces 2.4 kg/hour for Light Roast criteria, for Medium Roast criteria produces 1.7 kg/hour, and for Dark Roast criteria produces 0.8 kg/hour. The average temperature distribution for Light Roast material is 97 ° C, Medium Roast is 110.83 ° C, and Dark Roast is 131.25 ° C.

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